MODELING THE 60μm/20cm INFRARED-TO-RADIO RATIO WITHIN SPIRAL GALAXIES

M. D. BICAY and G. HELOU
Infrared Processing and Analysis Center
California Institute of Technology
Pasadena, CA 91125, USA

The remarkably tight *global* correlation between integrated far-infrared and radio continuum emission from spiral galaxies has recently stimulated interest in determining whether the relation holds ***spatially*** within galaxies (Wainscoat ***et al.*** 1987; Beck and Golla 1988; Bicay ***et al.*** 1989, hereafter Paper I). We report here on a detailed comparison of the distribution of 60μm infrared and 20cm radio continuum emission within 25 galaxies, mostly disk spirals. Local maxima in the thermal infrared and predominantly nonthermal radio maps are found to be spatially coincident on scales $<0.3h^{-1}$ kpc in nearby galaxies. Superimposed on this broad correlation, we observe in the disks of most sample galaxies a slow decrease in the 60μm-to-20cm ratio Q_{60} with increasing radius. Values of Q_{60} within the central regions are often enhanced by a factor of 3 or more compared to the outer disks, whereas the corresponding enhancement in radio surface brightness is greater by at least an order of magnitude. The radial gradient in Q_{60} is most easily identified in nearby, face-on galaxies (e.g. NGC 5236, NGC 6946) due to the limited *IRAS* angular resolution. However, the gradient is also observed along the major axis of highly inclined systems (e.g. NGC 55).

The observed radial gradients in Q_{60} suggest that spiral galaxies are characterized by an infrared disk with a shorter scale length than that of the radio continuum disk. We introduce a phenomenological model that relates the radio and infrared disks via a smearing process due to cosmic-ray propagation. The basic tenets of the model, as explained in Paper I, are based on two assumptions: (***i***) there exists a tight coupling between the origins of the dust-heating radiation and the radio-emitting cosmic-ray electrons, as suggested by the constancy of the global infrared-to-radio ratio in galaxies displaying various levels of star formation activity; and (***ii***) a steady-state picture adequately describes star formation activity ***within the disk*** on scales corresponding to the *IRAS* resolution.

There are two observational constraints on the model: (***i***) the 20cm maps of Condon (1987), and (***ii***) the radial gradients in Q_{60}. The underlying source distribution is described as an exponential disk and equated with the infrared disk, neglecting the smoothing associated with the reprocessing of ultraviolet photons to infrared radiation (see Paper I for rationale). The infrared disk is convolved with a smoothing function associated with cosmic-ray (CR) transport to yield the observed radio disk.

We obtain the following results after successful application of the model to various galaxies: (1) a Gaussian smoothing function yields excessively broad radio disks, indicating that CR spreading is not dominated by random-walk diffusion; (2) an exponential smoothing function of the form $I(r)=I_o \exp(-r/r_o)$ provides better fits to the 20cm and Q_{60} data; (3) the exponential scale length of the CR smoothing function in modeled galaxies is on the order of 1-5 kpc; and (4) some galaxies display unresolved central peaks in the radio and Q_{60} (and hence the infrared) distributions. The latter observation, coupled with

R. Beck et al. (eds.), Galactic and Intergalactic Magnetic Fields, 237–238.

the inability of the model to account for perturbations in Q_{60} due to discrete disk features (e.g. spiral arms, HII regions), is consistent with assumption (*ii*) above being violated in localized regions of active star formation. Figure 1 presents model results for two nearby galaxies superimposed on the derived Q_{60} values.

The fact that an exponential CR smoothing function fits the data on arcminute scales suggests that the critical process governing CR confinement may be a form of the "leaky-box" model, in which CR electrons diffuse freely inside the galactic disk and are partially reflected at the disk boundaries. The central point-like radio source implies that the electrons accelerated in the central region do not diffuse into the disk. This may reflect a preference for poloidal magnetic field structures in the central regions of disks, which would allow CR electrons to escape directly from the center. Further interpretation of these model results, and the implications regarding galactic magnetic fields, are presented in a companion paper (Helou and Bicay: these Proceedings).

This research was supported through the *IRAS* Extended Mission Program by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. M.D.B. gratefully acknowledges the support of a National Research Council Research Associateship.

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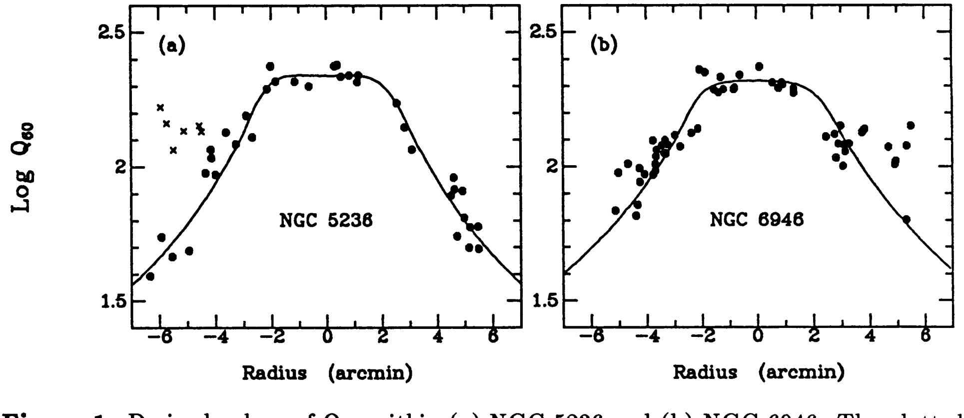

Figure 1. Derived values of Q_{60} within (a) NGC 5236 and (b) NGC 6946. The plotted points fall along a line whose position angles (measured east of north) are 118° ± 6° (a) and −60° ± −13° (b). Superimposed are the best-fit model results obtained using the following exponential scale lengths r_o for the infrared disk and cosmic-ray smoothing function, respectively: (a) 1.8 kpc and 1.8 kpc; (b) 2.1 kpc and 2.1 kpc (where H_o =50 km s^{-1} Mpc^{-1}). The data points denoted by X in (a) are spatially coincident with supergiant HII regions. Values of Q_{60} at radii < 2.35′ are dominated by emission from the central point source, smeared by the *IRAS* 60μm beam.